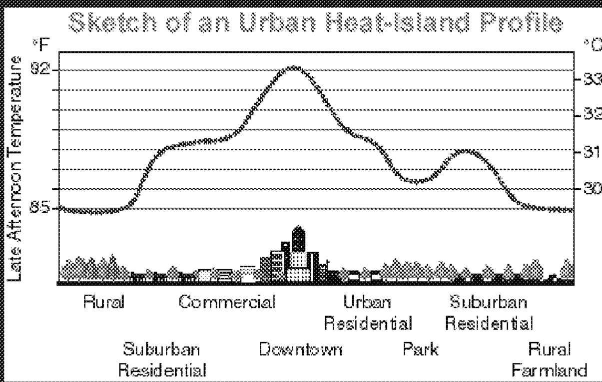
Benefit Measurement and Valuation

5. URBAN HEAT ISLAND

The USEPA describes the process by which urban heat islands form as follows: "As urban areas develop, changes occur in the landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist generally become impermeable and dry. This development leads to the formation of urban heat islands—the phenomenon whereby urban regions experience warmer temperatures than their rural surroundings" (US EPA n.d. a).



Source: Lawrence Berkeley National Laboratory

The urban heat island (UHI) effect compromises human health and comfort by causing respiratory difficulties, exhaustion, heat stroke and heat-related mortality. UHI also contributes to elevated emission levels of air pollutants and greenhouse gases through the increased energy demand (via greater air conditioning needs) that higher air temperatures cause. Additionally UHI puts a greater demand on outdoor irrigation needs thus increasing water demand and its associated energy uses. Green infrastructure practices within urban areas can help to mitigate UHI and improve air quality through increased vegetation, reduced ground conductivity and decreased ground level ozone formation.

Various studies have estimated that trees and other vegetation within building sites reduce temperatures by about 5°F when compared to outside non-green space. At larger scales, variation between non-green city centers and vegetated areas has been shown to be as high as 9°F. Likewise, recent studies done on permeable pavement have found that it reduces or lowers the negative impacts of UHI through its porosity, which serves to insulate the ground better and allow more water evaporation. Both of these effects aid in cooling temperatures and mitigating the UHI effect.

One study, evaluating the benefit of reduced extreme-heat events, estimates that, at a city level, 196 premature fatalities can be avoided in Philadelphia (over a 40-year period) by integrating green infrastructure throughout the city landscape to address its combined sewer overflows (McPherson et al 2006; Akbari et al 1992; Stratus 2009). According to figures from the USEPA (n.d. b), the value of a statistical life (VSL) is $7.4 million (in 2006 dollars). Thus, applied to the Philadelphia study, reductions in UHI-related fatalities could save over $1.45 billion. Likewise, the Lawrence Berkeley Lab Heat Island Group estimates that each one degree Fahrenheit increase in peak summertime temperature leads to an increase in peak demand of 225 megawatts, costing ratepayers $100 million annually (Chang 2000).

While the benefits of mitigating the UHI are important to community health and vitality, current valuation of these benefits is not extensive enough to work through quantifying methods and equations in this section.

Benefit Measurement and Valuation

6. COMMUNITY LIVABILITY

Using green infrastructure for stormwater management can improve the quality of life in urban neighborhoods. In addition to the ecological and economic values described elsewhere in this handbook, the goods and services provided by urban vegetation and other green infrastructure practices carry socio-cultural values—aspects that are important to humans because of social norms and cultural traditions. This set of related benefits is grouped under the umbrella category of 'community livability' to describe the many ways in which increasing the use of green infrastructure can improve neighborhood quality of life. Community livability is classified into four categories:

- Aesthetics
- Recreation
- Reduced noise pollution
- Community cohesion

While all of these benefits carry significant value in communities, the literature regarding how to quantify their economic value is not extensive, widespread or well agreed upon at this time. Given the high levels of uncertainty involved in quantifying community livability benefits, this guide does not present methods and equations for quantification or valuation in this section. It does, however, points to ranges of benefit values that have been presented and proposed in various studies.

AESTHETICS

Increased greenery within urban areas increases the aesthetic value of neighborhoods. The positive impact of green infrastructure practices on aesthetics can be reflected in the well-observed relationship between urban greening and property value. People are willing to pay more to live in places with more greenery. To measure this value, various studies employ a Hedonic price method (calculating increases in property value adjacent to green features).

Several empirical studies have shown that property values increase when an urban neighborhood has trees and other greenery. For example, one study reported an increase in property value of 2–10 percent for properties with new street tree plantings in front (Wachter 2004; Wachter and Wong 2008). Another study done in Portland, Oregon, found that street trees add $8,870 to sale prices of residential properties and reduce time on market by 1.7 days (Donovan and Butry 2009). An extensive study on the benefits of green infrastructure in Philadelphia also explores the effect that these practices have on property values (Stratus 2009). While the authors conclude that property values are notably higher in areas with LID and proximity to trees and other vegetation, they also note the difficulty in isolating the effect of improved aesthetics and avoiding double-counting of benefits such as air quality, water quality, energy usage (often relating to heat stress) and flood control that also impact property values. In this study, a range of 0– 7 percent is presented as suggested in literature, and a mean increase of 3.5 percent is chosen (Status 2009). Ward et al. (2008) estimate property values in the range of 3.5–5.0 percent higher for LID adjacent properties in King County, Washington.

The Forest Service *Tree Guides*, referenced previously, provide estimates of the property value benefits trees provide in an urban setting. The property value benefit is found to be the second largest component of the total benefits derived from trees. Benefits are presented on a per tree basis, based on type and size of each tree as well its location.

Table 6.1
Annual Property Value Gains from 1 tree, 40-year average, Midwest Region

	Small tree: Crabapple (22 ft tall, 21 ft spread)	**Medium tree: Red Oak** (40 ft tall, 27 ft spread)	**Large tree: Hackberry** (47 ft tall, 37 ft spread)
Residential Yard	$4.50	$10.73	$23.44
Public Space	$5.32	$12.67	$27.69

Source: McPherson, E. et al. 2006

RECREATION

Green infrastructure has been shown to increase recreational opportunities (for example, walking the dog, walking or jogging on sidewalks, bench sitting or picnicking) when increased vegetation and treed acreage is added within a community. The value of added recreational opportunities is measured by the increase in recreational trips or "user days" gained from urban greening. Use values can then be assigned to the various recreational activity trips.

In one study, Philadelphia, Pennsylvania, estimated an increase of almost 350 million recreational trips (over a 40-year period) when utilizing green infrastructure within the proposed implementation of its *Green City Clean Waters* plan to control stormwater. The 2009 monetized present value of these added trips could amount to over $520 million (Stratus 2009). Furthermore, a report by the Trust for Public Lands for the Philadelphia Parks Alliance provided critical data on recreational uses, activities and visitation at parks in Philadelphia (Trust for Public Land 2008).

User Day Methodology

User day estimates from the Philadelphia study, although not necessarily universal, may provide a helpful starting point for valuing improved recreation from green infrastructure and increased vegetation.

- 1 additional vegetated acre provides ~1,340 user days per year
- 1 additional vegetated acre provides ~27,650 user days over a 40-year period
- 1 user day provides ~$0.71 in present value for 40-year project period (Stratus 2009)

This translates to a benefit of about $951.40 for each additional vegetated acre per year and about $19,631.50 for each additional vegetated acre over a 40-year project period.

For a complete methodology, please refer to the Stratus (2009) report.

Another approach to valuing recreation is determining the avoided costs in connection to health benefits. An example of this would be studies that correlate lowered medical expenses with increased levels of routine physical activity. In a 2000 study, researchers found that when previously inactive adults regularly incorporated moderate physical activity into their routines, annual mean medical expenditures were reduced by $865 per individual (Pratt et al. 2000).

REDUCED NOISE POLLUTION

Green infrastructure, particularly vegetative practices and permeable pavement, have the added benefit of reducing noise pollution. Planes, trains and roadway noise are significant sources of noise pollution in urban areas—sometimes exceeding 100 decibels, which well exceeds the level at which noise becomes a health risk.

A study in Europe using porous concrete pavement found a reduction in noise level of up to 10 decibels (Olek et al 2003;

Gerharz 1999). Likewise, the British Columbia Institute of Technology's Centre for the Advancement of Green Roof Technology measured the sound transmission loss of green roofs as compared to conventional roofs. The results found transmission loss increased 5–13 decibels in low- and mid-frequency ranges, and 2–8 decibels in the high frequency range (Connelly and Hodgson 2008). Hedonic pricing studies assessing the impact of road and aircraft noise on property values find average reductions in property value per one decibel increase in noise level of 0.55 percent and 0.86 percent, respectively (Navrud 2003).

COMMUNITY COHESION

One way that green infrastructure can make communities better places to live is through its effect on 'community cohesion'—improving the networks of formal and informal relationships among neighborhood residents that foster a nurturing and mutually supportive human environment (Sullivan, Kuo and Depooter 2004).

A study done by the Landscape and Human Health Laboratory at the University of Illinois at Urbana/Champaign (UIUC) found that, "Exposure to green surroundings reduces mental fatigue and the feelings of irritability that come with it. . . . Even small amounts of greenery . . . helped inner city residents have safer, less violent domestic environments." (Kuo and Sullivan 2001b).

Another study documents a link between increased vegetation and the use of outdoor spaces for social activity, theorizing that urban greening can foster interactions that build social capital (Sullivan, Kuo and Depooter 2004). Related to this effect, a further study found a meaningful relationship between increased greenery and reduced crime (Kuo and Sullivan 2001a).

Urban Agriculture Opportunities

As urban populations grow and the costs associated with rural food production and distribution continue to increase, urban agricultural systems are being considered in order to address concerns related to food security and cost (Argenti 2000). According to the USDA, 15 percent of the world's food supply is currently produced in urban areas (AFSIC 2010).

Green infrastructure practices such as green roofs and tree planting can provide increased opportunities for urban agriculture and urban foraging. Urban agriculture can include a multitude of benefits to urban areas, including economic development, recreational and community-building activities, educational opportunities for youth and increased habitat within the urban ecosystem.

While local food production via green infrastructure provides a variety of valuable community benefits, the current state of its valuation is not extensive enough to work through quantifying methods and equations in the guide at this time.

7. HABITAT IMPROVEMENT

Many vegetated green infrastructure features can improve habitat for a wide variety of flora and fauna. Rain gardens and other vegetated infiltration features hold particular value in this regard insofar as they perform best when planted with native species. Ecological economists recognize two aspects of habitat which are preconditions for the provision of a whole array of ecosystem services. First, habitat is living space for both resident and migratory species. Second, habitat provides nurseries for species which live their adult lives elsewhere.

Habitats are typically economically valued using either contingent valuation methods (especially where the conservation of an endangered species is concerned) or using the market price of traded goods that are harvested at the habitat in question (or of traded goods that are harvested elsewhere but for which the relevant habitat provides breeding and/or nursery grounds). The latter method can be useful, for example, in the case of coastal estuaries that provide nurseries for commercially harvested fish, but this approach is less applicable to the relatively small-scale urban vegetated features in question here. Contingent valuation studies might be more useful, but unfortunately, few have been conducted examining the habitat value of urban green space. Thus, this guide does not attempt to provide a framework for valuing this benefit.

Benefit Measurement and Valuation

8. PUBLIC EDUCATION

The USEPA (2008b) has listed public education as one of its six stormwater best management practices, further supporting the need for communities to be educated about water conservation and stormwater management. This is particularly important given the public's lack of understanding about the primary causes of and solutions to water pollution problems. A 2005 report by the National Environmental Education & Training Foundation (NEEFT) came to the following conclusion:

"78 percent of the American public does not understand that runoff from agricultural land, roads, and lawns, is now the most common source of water pollution; and nearly half of Americans (47 percent) believes industry still accounts for most water pollution (NEEFT 2005)."

While quantifying and valuing public education is difficult and the guide does not attempt to do this, educating and informing the general public about the efficient use of water resources is a valuable service that can build support for better water management decisions in the future. It is a vital precursor to achieving widespread adoption of green infrastructure solutions and realizing the many benefits they offer to communities.

Example Demonstration 1: Benefit Assessment of a Single Green Roof

The demonstration below walks through the quantification and valuation steps for the benefits provided by the 5,000 square foot green roof example that recurs throughout this handbook. This example is not a full lifecycle analysis and therefore does not take into account long-term benefits such as extended longevity of the roof membrane.

The table below is set up such that one may easily compile the annual monetary gains from each benefit. Although the green roof's net monetary benefit is calculated at the end of the table, please keep in mind that this will be an underestimate of the green roof's true value. Some benefits, such as reducing the urban heat island effect or improving community livability, are not quantifiable or valued at this time. In addition, this example only considers the benefits from one relatively small project. Initiating a community-wide program that embeds green infrastructure throughout the urban landscape would provide far greater benefits.

Benefit	Step 1: **Benefit Quantification** resource unit(s)	Step 2: **Benefit Valuation** resource unit * price	Annual Benefit $
Reduces Stormwater Runoff	**Annual Stormwater Retention Performance:** 71,100 gal retained *(Example 1.1)*	**Value of Annual Avoided Treatment Cost:** 71,100 gal * $0.0000919/gal = $6.53 *(Example 1.6)*	$6.53
Reduces Energy Use	**Annual Building's Cooling (electricity) Savings (kWh):** 1,122 kWh *(Example 2.1)*	**Value of Annual Building's Cooling Savings:** 1,122 kWh* $0.0959/ kWh = $107.60 *(Example 2.5)*	
	Annual Building's Heating Natural Gas Savings (Btu): 36,158,750 Btu *(Example 2.2)*	**Value of Annual Building's Heating Savings:** 36,158,750 Btu * $0.0000123/Btu = $444.75 *(Example 2.5)*	
	Annual Off-site Water Treatment Electricity Savings (reduced treatment needs of 71,100 gal): 110.77 kWh *(Example 2.4)*	Annual Off-site Water Treatment Electricity Savings will not be valued here because the value has already been accounted for above *(Example 1.6)*.	
	Total Annual Electricity Savings (kWh, from on-site and off-site benefits): ∑ 1,122 kWh in cooling savings + 110.77 kWh in water treatment electricity savings = 1,232.77 kWh	The Total Annual Electricity Savings will not be valued here to prevent double counting. Instead, it is used to quantify "Air" and "Climate" benefits.	$107.60 + $444.75
Improves Air Quality *Note: The figures used here only account for the benefits of reduced NO_2. Similar steps should be performed for the other criteria pollutants, when possible.*	**Annual Direct NO_2 Uptake:** Lower Bound = 1.50 lbs NO_2 Upper Bound = 2.39 lbs NO_2 Average = 1.95 lbs NO_2 *(Example 3.1)*	**Value of Total Annual NO_2 Benefit:** 30.19 lbs NO_2 * $3.34/lb NO_2 = $100.83 *(Example 3.6)*	
	Annual Indirect Reduction in NO_2 Emissions (from reduced electricity and natural gas): 28.24 lbs NO_2 *(Example 3.5)*		
	Total Annual NO_2 Benefit (Direct uptake using the average NO_2 uptake value + indirect avoided emissions): ∑ 1.95 lbs NO_2 + 28.24 lbs NO_2 = 30.19 lbs NO_2 *(Example 3.6)*		$100.83
Reduces Atmospheric CO_2	**Total Annual Indirect Benefit** (from electricity and heating natural gas savings): 1,639.58 lbs CO_2 + 4,226.6 lbs CO_2 = 5,866.18 lbs CO_2 *(Example 4.5)*	**Value of Total Annual Climate Benefit:** 6,486.41 lbs CO_2 * $0.00756/ lb CO_2 = $49.04 in total annual climate benefits *(Example 4.6a)*	
	Annual Direct Carbon Sequestration Benefit in CO_2 Equivalent (multiplying lbs C from Example 4.1 by conversion factor): = 620.23 lbs CO_2 *(Example 4.6)*	*Note: Here the lower bound (EU's ETS Carbon Price) of the range of carbon pricing was used. Keep in mind that this provides a conservative estimate of the economic, environmental and other social values of carbon abatement.*	
	Total Annual Climate Benefit (Direct + Indirect): ∑ 620.23 lbs CO_2 + 5,866.18 lbs CO_2 = 6,486.41 lbs CO_2 *(Example 4.6)*		$49.04
		Total Annual Benefit (∑ Annual Benefits)	**$708.75**

Example Demonstration 2: Benefit Assessment of a Neighborhood Scale

This demonstration will walk through the quantification and valuation steps for scaling up the benefits of converting a hypothetical area of Chicago rooftops to green roofs. Following from Example Demonstration 1, these calculations show, in simplified terms, how scaling up the build out of green roofs has the potential to provide significant benefits to a community or urban area.

In this hypothetical demonstration, the City of Chicago plans to implement a green roof program to cover 1,200,000 square feet of viable rooftop area (assuming each green roof is 5,000 square feet in area) and calculates the total annual value of implementing this program. For reference, this converted area covers approximately five city blocks, provided that the average size of a city block in Chicago is 239,580 square feet[6].

In order to scale up the green roof benefits found earlier, one must calculate the number of roofs affected over the converted area (which will become the multiplier used to scale up the benefits):

1,200,000 SF area to be converted / 5000 SF per roof = 240 converted rooftops

The table below summarizes the benefits and corresponding monetary value of converting these 240 rooftops into green roofs.

Benefit	Annual Benefit ($) per 5,000 SF green roof (Example Demonstration 1)	Annual Benefit ($) from scaled green roof program (= annual benefit per roof * 240 converted roofs)
Reduces Stormwater Runoff	$6.53	$6.53 * 240 = $1,567.20
Reduces Energy Use	$107.60 + $444.75= $552.35	$552.35 * 240 = $132,564.00
Improves Air Quality *Note: The figures used here only account for the benefits of reduced NO_2. Similar steps should be performed for the other criteria pollutants, when possible.*	$100.83	$100.83 * 240 = $24,199.20
Reduces Atmospheric CO_2	$49.04	$49.04 * 240 = $11,769.60
Total Annual Benefit ($\sum$ Annual Benefits)	**$708.75**	**$708.75 * 240 = $170,100.00**

[6] Average block size for the City of Chicago was determined using U.S. Census block group data collected from the Center for Neighborhood Technology's H+T® Affordability Index: 5.5 acres = 239,580 SF. Since block size varies from city to city, it is important to use local numbers for block area when available (CNT 2010b).

The previous calculations rely on a few central assumptions. First, the entire area in question will be converted into working and viable green roofs. Second, any additional scaling of green roof area will yield proportional benefits (hence the constant multiplier). Although the economic, environmental and social benefits of green roofs are calculated here, the total benefit value does not include a number of benefit categories, most notably reduced urban heat island effect, improved community livability, enhanced water quality and reduced flood risk. This guide has not attempted to quantify and value these benefits at this time, but they can be expected to significantly increase the overall value of the green roof.

It is also important to note that this example only considers the benefits from a relatively small application of green roofs. Initiating an even larger community-wide program that includes other forms of green infrastructure spread throughout the urban landscape would provide even greater benefits.

A similar example of a scaled-up urban application of green roofs has been done for the city of Washington, D.C. This case study looks at the impacts of green roofs over different coverage scenarios and details a methodology for analyzing an "opportunity area" for green roof implementation within the city (Deutsch et al. 2005). Findings show that both stormwater and air quality benefits are significant for a 20 percent green roof coverage scenario. These benefits include a predicted 13 percent reduction in CSO discharges and the same air quality benefits as would be provided by approximately 19,500 trees. The report concludes that the 20 percent green roof coverage case is both a "reasonable" and "feasible" target for the District of Columbia (Deutsch, B. et al. 2005).

Considerations and Limitations

This section explains key considerations and limitations to the preceding quantitative research and analysis. Due to the nature and scope of this report, every local project will have its own set of case-specific variables and uncertainties that must be evaluated. Particularly when undertaking a more rigorous benefit analysis of a specific green infrastructure program, please keep the following considerations in mind.

Full Life-Cycle Analysis

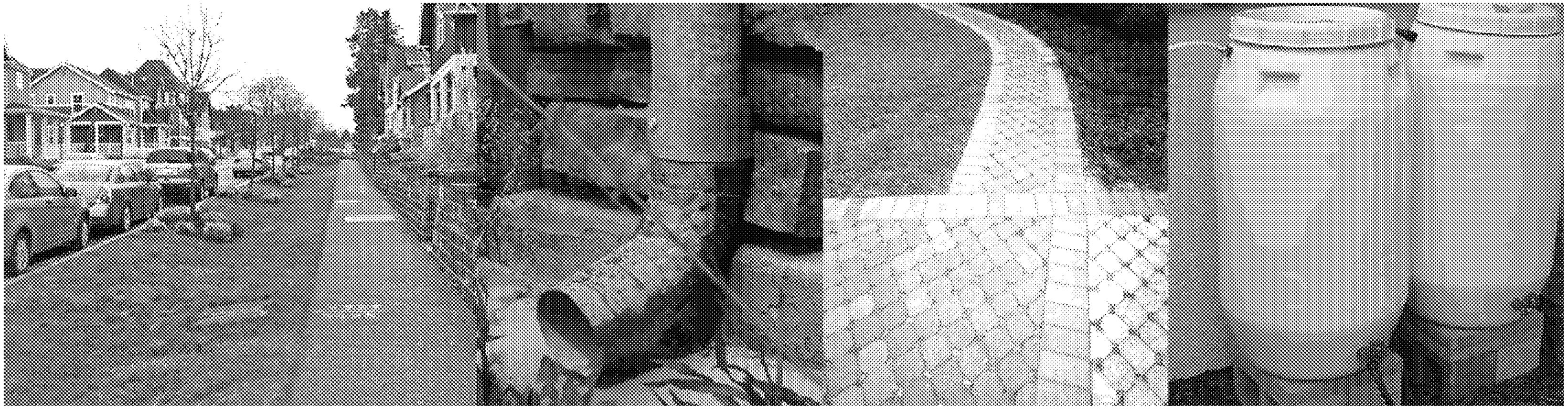
While a full life-cycle analysis is an important piece of the decision making process, it is beyond the scope of this guide, which has focused only on benefits. That said, it is important to note that when performing this type of valuation analysis, consideration of the counterfactual comparison is necessary. In other words, clearly defining what is being compared is critical. For example, is the analysis comparing whether or not to use green infrastructure instead of conventional grey infrastructure, or is the comparison between no change and the implementation of a green infrastructure project? This counterfactual understanding is important when valuing the overall costs and benefits of an action and should be clearly defined prior to working through a life-cycle analysis comparison.

Local Performance and Level of Benefits Realized

Detailed considerations of local and site-specific variables that impact green infrastructure performance are largely addressed in the previous quantitative section on a case-by-case basis. However, the need for local data when working through a framework for valuing a green infrastructure project or program remains crucial.

Recall that, as stated previously, the placement of trees relative to neighboring buildings will impact the amount of energy saved or that the media depth of a given green roof will impact its water retention capacity. Site-specific considerations should be made (when possible) for each benefit analysis in order to more precisely calculate the benefits accrued from a given project.

Regional and local variables, such as climate, also play a large role. Two green infrastructure installations with the exact same specifications can result in drastically different levels of benefits when implemented in different locations. For example, climate largely determines the reduction in building energy use resulting from trees. As discussed in the "Energy" section, shading



buildings in cool regions can actually cause an increase in energy demand, while reducing wind speeds in warm regions has little to no impact.

Spatial Scaling and Thresholds

Given the lack of large-scale green infrastructure programs and research analyzing their performance, it is uncertain whether one can estimate potential benefits from a community-wide program simply by scaling up smaller-site data. In other words, the benefits from a specific practice may or may not have a linear relationship to the scale of a project.

Some examples used in this guide provide estimates for linear multipliers (for example, the energy saved per square foot of a green roof in the "Energy Section") and rely on the assumption that the benefit from one unit of a practice is proportional to the benefit from 100 units of the same practice. The complexity of natural functions, however, does not necessarily lend itself to such a simplified aggregation, and system level considerations are important.

Instead of having a linear relationship, it is also possible that green infrastructure could function similarly to the concept of an "economy of scale." This would be the case if the benefits accrued from a practice have a proportionately greater effect on a large scale than they would if practiced over a small area. In effect, the green infrastructure practice would provide the maximum level of benefit only after achieving a certain scale of implementation. For example, the water quality improvement from a constructed wetland would be significantly and disproportionately larger than the water quality improvement from a smaller-scale rain garden.

An equally important consideration within spatial scaling is the concept of an ecological threshold, which can be described as "the point at which there is an abrupt change in an ecosystem . . . or where small changes in an environmental driver produce large responses in the ecosystem" (Groffman et al 2006). For example, urban heat island mitigation benefits that result from green infrastructure practices may only be realized at an as yet unknown level of incremental spatial implementation. A forest may provide significant cooling benefits, while a smaller number of individual trees in an urban area may have a negligible impact.

Temporal Considerations and Scale

Discounting

When evaluating an investment, economists use a process known as discounting, or present-value determination, to calculate the present-dollar equivalent of an investment's future benefits. In other words, discounting "translate[s] the values of future impacts into equivalent values in today's monetary units" (Goulder and Stavins 2002).

The term "discounting" refers to the adjustment one makes to account for future uncertainty (or the opportunity cost of money: a dollar today is not worth the same as a dollar five years down the road). Our society generally values what an investment gives us in the present more than what we might get for it in the future. The reason for this is future uncertainty, and as such, the future value or benefit of an investment must be adjusted or discounted. It is a technique widely used in benefit-cost analyses to understand and compare a project's implications (its rate of return) over a given temporal scale. Please note, however, that "applying a discount rate is not giving less weight to future generations' welfare" (Stavins 2005). Instead, it simply converts the net impacts from an investment over time into common units (Stavins 2005).

The controversy over discounting arises not from the concept itself but from how one determines which "social discount rate" is appropriate to use, particularly when evaluating environmental considerations. When a discount rate is chosen, there is an implicit judgment made about the value of the future. Oftentimes, an individual and a community value future benefits from a given green infrastructure project or program differently. Furthermore each green infrastructure practice behaves differently over time and requires specific considerations when performing discounting calculations. For these reasons, this guide makes no specific discount rate recommendations.

When proposing a large or long-term green infrastructure project, an in-depth discounting analysis, tailored to the specific case at hand, should be performed.

Operation and Maintenance

As is the case with conventional stormwater controls, green infrastructure depends upon regular maintenance to realize maximum benefits. When undertaking a green infrastructure project, it is important to fully consider the life cycle of the vegetation or capital used. Understanding the amount of maintenance involved in achieving the full benefit from a given practice is extremely important when undertaking large-scale green infrastructure. Many benefits of GI depend on regular maintenance. For example, vegetated green infrastructure elements, like plants on a green roof or tree plantings, will only sequester carbon as long as someone properly and routinely maintains them.

Other more capital-intense green infrastructure may require operational maintenance (for example, regularly cleaning permeable pavement for optimal performance) and repair over time to extend the life of the practice and to ensure that maximum benefits are realized. Conventional grey infrastructure, however, requires regular maintenance as well. Full lifecycle analysis must also evaluate operation and maintenance costs of conventional projects, which periodically require intense capital investments themselves.

Pricing Variability

During the valuation step (Step 2) in each subsection of the "Economic Valuation in Action" part of this guide, market prices are needed to calculate a final monetary value for each benefit. Although recommendations or sample prices for water treatment, electricity, criteria air pollutants and carbon can be found in the "Water," "Energy," "Air" and "Climate" sections, respectively, it is important to tailor these values to specific local data numbers whenever possible. The prices used in these calculations will have a significant impact on the magnitude of monetary value realized.

In addition, it is often difficult to find a strict market value for variables that may be too abstract or complicated to put in a market setting or in monetary terms. This lack of certainty is most pronounced in sectors that currently have few or no markets from which to derive prices. Prominent examples of this uncertainty can be taken from the debate over the value of a statistical life or the price of carbon. Property values and hedonic pricing (i.e. the perceived value of a good or service) also have an inherent degree of uncertainty and subjectivity when used to derive the value of a good or service.

For the purpose of this guide, it is necessary to rely on existing estimates to value the benefits of green infrastructure. However, given local variations, pricing uncertainty and economic fluctuation, market prices will likely vary over time. Please keep these considerations in mind when undertaking any in-depth analysis of green infrastructure valuation.

Double Counting

Summing up the benefits from multiple green infrastructure practices can be extremely complex, as many of the benefits are interconnected and correlated. This creates the risk of double counting or capturing the value of the same benefit multiple times. For example, in the "Water" section, valuation estimates from a property value study may account for both water treatment costs and reduced risk of flooding. Many of these specific precautions are directly addressed in each of the valuation sections.

It is important to keep in mind which aspects of each benefit are being captured in each stage of the valuation. For example, valuing the benefit of direct cost savings from reduced water treatment needs captures the cost of the energy associated with the treatment. It is, therefore, not necessary to account for the direct cost savings from the reduced energy use associated with reduced water treatment. It is, however, important to still calculate the energy reduction associated with reduced water treatment needs, because it is unlikely that the reduced emissions associated with the reduced energy use are captured in the direct cost savings from the reduced water treatment needs.

Also, as discussed in detail in the "Climate Change" and "Air Quality" sections, remember that the direct and indirect benefits realized from trees are combined. Because the *Tree Guides* consider carbon sequestration and avoided carbon dioxide emissions from reduced energy use in conjunction, it is important to not include these benefits twice. The same holds true for pollutant uptake and avoided emissions resulting from trees.

Case Studies: Valuing Green Infrastructure Across the United States

Throughout the United States, there is a growing recognition of the benefits green infrastructure provides to communities. Many municipalities have begun to recognize the additional benefits green infrastructure and effectively incorporate these practices. The following case studies illustrate the process these municipalities have implemented and what some of the findings have been.

Aurora, Illinois

Faced with aging infrastructure, an already impaired local water way and projected population growth, Aurora wanted to strengthen its downtown economy while providing environmentally and economically sustainable solutions to its stormwater management issues.

The City's leaders recognized the potential value green infrastructure could provide in solving some of these issues and began to analyze where GI might be appropriate. The resulting plan, highlighted in Aurora's *Rooftops to Rivers* program, seeks to bring green infrastructure to scale and attain quantifiable, replicable results.

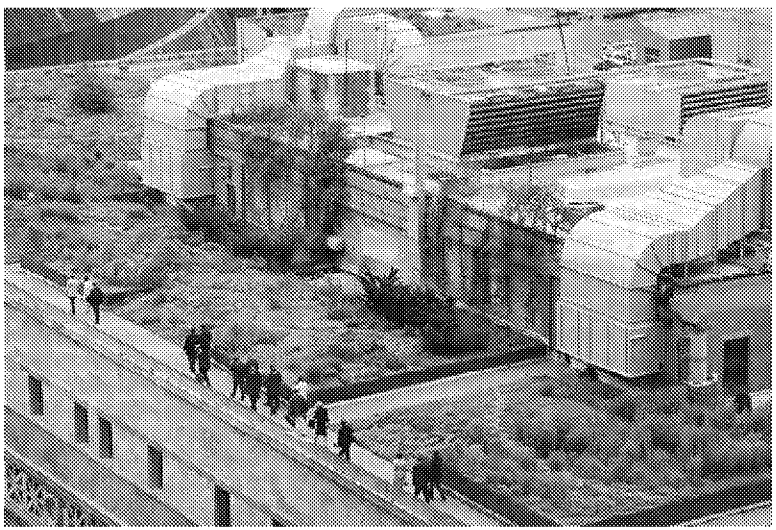
Early estimates conclude that current stormwater runoff issues within the city could be substantially reduced, with "nearly 141 million cubic feet of stormwater (about 1.05 billion gallons) [diverted] from the sewer" (NRDC 2009). These results would yield about $108,632 in annual savings and reduce energy use by 1.37 million kWh, or the equivalent of 990 metric tons (about 2.2 million pounds) of carbon dioxide.

Chicago, Illinois

In an effort to address and plan for the future impacts of climate change, including increased flood risks and public health stresses, Chicago adopted and is currently implementing its *Chicago Climate Action Plan*. The plan emphasizes green infrastructure

(including green roofs, tree plantings and rainwater harvesting) as a strategy for adapting to the risks this region faces as climate change develops (Chicago 2008).

Chicago has also been a leader in promoting urban green roofs due to the combined sewer overflows problems within the region. The 20,000 square foot roof atop City Hall has helped decrease stormwater runoff and improve urban air quality by reducing the urban heat island effect around the site. Since its completion in 2001, the green roof has saved the city $5,000 a year in energy costs (Chicago Green Roofs 2006). Monitoring of local temperatures found that the "cooling effects during the garden's first summer showed a roof surface temperature reduction of 70 degrees and an air temperature reduction of 15 degrees" (ASLA 2003). To date, Chicago has over 400 green roof projects in various stages of development, with seven million square feet of green roofs constructed or underway.



Milwaukee, Wisconsin

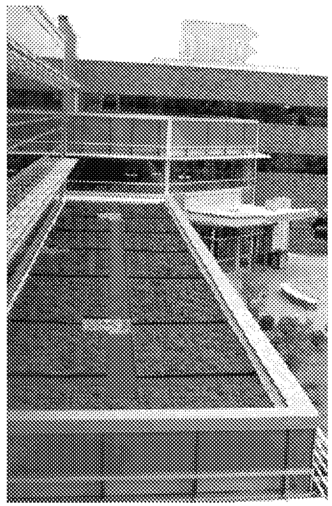
In an effort to reduce the occurrence of combined sewer overflows and reduce stress on aging grey infrastructure, the Milwaukee Metropolitan Sewerage District (MMSD) created a program called GreenSeams, which purchases upstream land for infiltration and riparian services. The program makes voluntary purchases of undeveloped, privately owned properties in areas expected to have major growth in the next 20 years. It also purchases open space along streams, shorelines and wetlands.

MMSD estimates that the total acreage holds over 1.3 billion gallons of stormwater at a cost of $0.017 per gallon. In contrast, one of its flood management facilities holds only 315 million gallons at a cost of $0.31 per gallon (MMSD 2010). While the comparison is not an apples-to-apples application, Milwaukee has found that, for managing stormwater and its potential flooding and overflow problems in urbanized areas, upstream conservation and the use of green infrastructure is cheaper than capital infrastructure build-out. This type of GI program works to save money for both the utility and its ratepayers.

New York, New York

Like most municipalities across the country, New York City (NYC) faces economic challenges. It must look at new strategies for getting the greatest amount of value out of every dollar invested in infrastructure. Due to its high percentage of impervious surfaces, the city generates a significant volume of stormwater runoff. In addition, NYC's aging infrastructure is under increasing pressure due to current and projected population growth. In an effort to address these issues while providing benefit to its residents, the city has adopted a Green Infrastructure Plan as part of its PlaNYC initiative. The plan presents "an alternative approach to improving water quality that integrates green infrastructure, such as swales and green roofs, with . . . smaller-scale grey or traditional infrastructure" (NYC 2010). One of its goals is to manage 10 percent of the runoff from impervious surfaces in combined sewer watersheds through these detention and infiltration approaches.

Additionally, since 1991, New York City has committed upwards of $1.5 billion toward maintaining and preserving its source waters in the Catskill and Delaware Watersheds (NYC DEP 2006). This initiative has thus far eliminated the need for a filtration plant that could cost as much as $10 billion. The city has not only improved its water quality, it has reduced the potential cost of water supply service to its ratepayers and reduced downstream flooding concerns. It has at the same time increased habitat and recreational opportunities for surrounding communities.



Philadelphia, Pennsylvania

Philadelphia faced the fact that conventional grey infrastructure approaches to managing the region's growing stormwater management issues would be cost prohibitive and would not adequately enable the City to meet its water quality standards. So, it turned to green infrastructure for possible solutions. The City hired Stratus Consulting to do a triple bottom-line assessment comparing traditional and green infrastructure. The final report's analysis shows that the net present-value of the benefits from green infrastructure greatly outweigh those of traditional grey infrastructure. For example, the city-wide implementation of green infrastructure at a 50 percent LID level—an option that would manage runoff from 50 percent of impervious surfaces in Philadelphia through green infrastructure—would provide a net benefit of $2,846.4 million. A 30-foot tunnel—the grey infrastructure option—would provide a net benefit of only $122 million (Stratus 2009).

In seeing the additional value that green infrastructure would provide its residents, Philadelphia has gone on to create a long-term combined sewer overflow control plan that invests heavily in GI initiatives. The program, titled *Green City Clean Waters*, is designed "to provide many benefits beyond the reduction of combined sewer overflows, so that every dollar spent provides a maximum return in benefits to the public and the environment" (PWD 2009).

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